MANAGEMENT STRATEGIES FOR LOW LEVEL RADIOACTIVE WASTE DISPOSAL*

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MANAGEMENT of low level radioactive waste has become a complicated subject, less because of technical difficulties than because of the extraordinary sociopolitical ramifications that have proliferated during the past decade. It has often been said that the problems associated with radioactive waste management are less than 10% technical and more than 90% public relations.

THE STANDARDS OF PERMISSIBLE RADIATION EXPOSURE

Assurance of safe management of radioactive material requires sufficient knowledge of the biological effects of radiation to permit establishment of socially acceptable standards of permissible exposure. Radiation protection has received worldwide attention for many decades and is far more developed, both scientifically and philosophically, than environmental toxicology generally. In a large measure this is due to the work of international and national bodies concerned with radiation protection. The International Commission on Radiological Protection was formed exactly 60 years ago, in 1928. One year later the National Council on Radiation Protection and Measurements was formed in the United States. In 1955 the General Assembly of the United Nations established the U.N. Scientific Committee on the Biological Effects of Atomic Radiation, and that organization has been remarkably effective in gathering information from all over the world and assembling it in reports that are issued periodically and are classics in international scientific collaboration. No organizations comparable to these are concerned with the health effects of the chemicals to which we are exposed.

The establishment of radiation protection standards is complicated by the assumption that a threshold does not exist for the carcinogenic and genetic

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effects of exposure.[1] If a threshold did exist, as is true for the chemical toxicity of many substances, safety could be assured by setting the permissible dose below the threshold, the definition of which requires scientfic judgement. However, once it is assumed that a threshold does not exist, the question is no longer "What is the safe dose," but "How safe is safe." The latter question cannot be answered by scientists alone. The acceptability of risk requires a social rather than a scientific judgement.

If a threshold does not exist, no dose level assures absolute safety. Any exposure, however slight, increases the probability that cancer or genetic effects may develop. The probabilities of such effects at doses of the order of those to which the public is exposed from the operation of low level radioactive waste facilities are finite, though vanishingly small. Therefore, it must be assumed that the risks are likewise finite, though vanishingly small. This reasoning is inherent in the assumption of a linear dose-response relationship, and is the basis of the unwillingness of the public to accept any additional radiation exposure above the natural background despite the fact that the background normally varies considerably, and the "permissible" exposures are well within its range of normal variability.

The regulatory agencies and bodies such as the International Commission on Radiological Protection and National Council on Radiation Protection that provide basic guidance to them have solved this problem by setting the allowable radiation exposures at levels that, *at a maximum*, will result in risks to the workers or to the general population no greater than the risks accepted from other industrial or commercial activities generally considered to be safe. The Environmental Protection Agency and Nuclear Regulatory Commission have established the offsite dose limitation at 25 mrem/y. The actual doses received by people living near low level nuclear waste facilities has actually been very much lower.

EARLY HISTORY OF LOW LEVEL RADIOACTIVE WASTE MANAGEMENT

Until about 1960 almost all low level waste was generated in facilities owned by the federal government, and waste repositories were located at or near them. Since there were no commercially operated repositories to accommodate the relatively small volume of waste then being generated by the private sector, the government also allowed those facilities to be used for wastes produced at biomedical institutions and research laboratories. There were as yet no privately owned nuclear power plants. At that time it was also permissible to dispose of wastes into the marine environment under licenses issued by the Atomic Energy Commission, but no such licenses were issued after 1960 and the method was discontinued completely after 1970, by which time commercial shallow land burial services had become available.[2]

In 1960 the decision was made that private waste generators would no longer be allowed to use the government facilities, and that commercial companies would be expected to provide disposal services under license from the Atomic Energy Commission. The first such facility began operation in Beatty, Nevada, in 1962, and by 1971 six commercial facilities were in operation, using the method of shallow land burial.

It was not long before operating deficiencies were reported at all the commercial burial grounds. Some shipments were arriving improperly packaged. Trenches were not properly designed, and surface subsidence created what became known as the ''bathtub effect'' because rainwater accumulated in the depressions and infiltrated the stored wastes. At one site, in Beatty, Nevada, workers at the site were pilfering contaminated tools and equipment, which were eventually recovered.

All of these developments indicated management deficiencies that required correction, but the subject received far more attention from the media and political circles than was warranted by the facts. It is important to emphasize that in no case was there significant exposure of either the workers at the sites or people living in the environs. Only at one site was there a measurable dose to any member of the public: that was at Maxey Flats, Kentucky, and was less than 3 mrem per year. It helps to put this figure into perspective to note that because of differences in the local geology the annual dose received from natural radiation on the island of Manhattan is about 15 mrem per year higher than that received across the river in the borough of Queens. Exposure of the public at Maxey Flats was only a small fraction of the dose received from natural sources of radiation and a small fraction of the annual dose permitted by the Nuclear Regulatory Commission and other regulatory agencies.

Options for Disposal of Low Level Waste

At the present time three options are available for disposal of low level radioactive wastes: on-site decay, incineration, and near surface burial.

Decay is a logical way to deal with short-lived nuclides used in biomedical facilities. I-131, with a half-life of 8 days, 14 day P-32, and 80 day S-35 need not be shipped offsite if storage space is available to allow for decay. At nuclear power plants, one of the principal waste nuclides is Cobalt-60, with a half-life of about five years. Storage of wastes in which Co-60 is initially the predominant nuclide is frequently feasible for a few decades at the power plant.

Two long-lived radionuclides, Tritium (H-3) and C-14, are widely used in biomedical institutions, and regulations permit combustible wastes containing these nuclides to be incinerated. Both H-3 and C-14 are produced naturally in the atmosphere by cosmic ray interactions, and the amounts that could be released to the environment by biomedical facilities would be trivial compared to that which already exists. Unfortunately, in some communities local rules prohibit this practice. It is not easy to understand why this is so. An incinerator that is able to safely incinerate pathological wastes should be more than adequate for the safe incineration of wastes containing C-14 and H-3.

In the public mind, the practice of near surface burial is frequently confused with land-filling. Landfills have been widely used for disposal of municipal and commercial wastes, and involve dumping of refuse into lowlands. The refuse is uncontained. Landfills are unsightly, frequently odoriferous, and are generally considered nuisances. In shallow land burial, the low level radioactive wastes are delivered to the disposal site in containers that are subject to strict design requirements, which depend on the level of radioactivity. The wastes are stacked in trenches typically 1,000 feet long, 100 feet wide, and 20 feet deep. When the trenches are filled to a predetermined height, contents are covered with soil, and the filled trench is graded. There should then be little or no radiation exposure on the surface of the trench above that received from natural radioactivity.

REPOSITORY DESIGN AND OPERATING CRITERIA

The potential danger to the public from operation of near surface burial facilities is that ground water may become contaminated by leaching of the wastes. The physical form in which the wastes are received and the manner in which they are packaged preclude the possibility of airborne radioactivity once the wastes are interred. There is no credible scenario by which the release of airborne material could result in significant exposure. There have been several million shipments of low level wastes during the past 40 years, and there have been a number of accidents both during handling of the packages and during highway transportation, but there were very few cases in which the packages were breached, and in no case was there exposure of the public.

Site selection, operation, and even closure and postoperational maintenance of the repository are regulated by the Nuclear Regulatory Commission in accordance with the requirments specified in Part 61 of Title 10 of the Code of Federal Regulations (10CFR61). Some of the states, including New York, have been delegated responsibility for assuring the safety of most of the uses of radioactive materials, including management of the low level radioactive waste facilities within their boundaries. Under the terms of the agreements, states are required to adopt regulations at least as strict as those promulgated by the Nuclear Regulatory Commission. Some states have adopted requirements stricter than those of the Commission, a subject to which I shall return later.

The basic objective of Part 61 is that the low level radioactive waste disposal facility should be sited, designed, operated, closed, and controlled after closure so that reasonable assurance exists that exposure of humans will be within the officially established limits. The term "reasonable assurance" is used in many regulations and should be taken as an acknowledgement that it can never be guaranteed with absolute certainty that the limits will not be exceeded. This is especially true in situations where the anticipated doses must be estimated before the facility has completed its life and, as in the case of most facilities, even before their construction has been completed. However, models used to estimate expected exposures are conservative, and the doses received in all cases with which I am familiar have been lower, often by orders of magnitude, than the estimated doses. This is illustrated by the histories of the six sites that have operated in the United States. It is important to remember that Part 61 was not issued until 1980, by which time the presently existing facilities had been in operation for up to 18 years. They were not subject to the rigid site selection, packaging, and operating procedures that are now specified in Part 61, but, despite the operating deficiencies noted above, there has been no significant exposure of the public.

Nuclear Regulatory Commission regulations for control of low level radioactive waste repositories were published in 1980 after a lengthy period of public comment. The environmental impact statement filed by The Commission[3] in compliance with the requirements of the National Environmental Policy Act was a document of several volumes in which many scenarios were analyzed to estimate doses likely to be received by the public. Since ground water is the vehicle by which the public is most likely to be exposed, this pathway is of special interest. However, in the environmental impact statement all exposure pathways were considered, including air, soil, ground water, surface water, plant uptake, and even exhumation by burrowing animals. For a site in the eastern United States it was estimated that the annual whole body dose to people affected by the repository would be 0.003 mrem.

This is the dose a person normally receives in a few minutes from normal exposure to natural radioactivity, which is about 100 mrem per year to most organs of the body, but averages 2,400 mrem per year to the bronchial epithelium due to radon in the atmosphere.[4] The estimated annual dose received from a nearby repository is also a small fraction of the 25 mrem whole body dose permitted for the public. Since the models used by the Commission to estimate dose commitments usually result in overestimates, the most likely conclusion is that there will be no exposure to the public. This conclusion is supported by the fact that there was so little exposure from the facilities built and operated according to the less stringent requirements that existed prior to publication of Part 61.

The main provisions of the regulations that pertain to radiological safety are the following: The annual dose to the members of the public must not exceed 25 mrem to the whole body, 75 mrem to the thyroid, and 25 mrem to any other organ. The site shall be capable of being characterized, modeled, analyzed, and monitored, which means that hydrogeological features can be described in quantitative terms. The direction and rates of movement of radionuclides leached from the wastes should be predictable. This is not possible at some sites. For example, if the wastes were to be placed in fractured bedrock, the path taken by seepage might be indeterminate. Its movement would be difficult. At the other extreme, if the wastes were to be placed in a clay bed with homogeneous properties, the movement of ground water could be well described, the exchange capacity of the clay would be well known, and the rates of movement of the individual nuclides would be predictable as a function of time. Design, operation, and closure of of the facility must ensure protection of individuals who inadvertently intrude into the site at any time after institutional controls over the disposal site are removed. The site must be well drained and not subject to ponding or flooding. The upstream drainage area must be minimized to avoid erosion of the site. The ground water must be of sufficient depth to prevent it from seeping into the repository. Voids between the packages of wastes must be filled to avoid subsidence. This is to avoid the "bathtub effect" discussed earlier. Liquid wastes must be solidified or packaged in sufficient suitable material to absorb twice the volume of the liquid. Solid waste shall contain less than 1% free standing noncorrosive liquid. Wastes must be noncorrosive, and be incapable of causing fire or explosion. They must also be structurally stable under the loads to be borne in storage.

There are innumerable additional requirements, among which is that the facility must be located on land owned by either the state or federal governments. Finally, there must be assurance of continuity of institutional control, including radiological monitoring, for 100 years after closure of the site. However, regulations state that institutional controls should not be relied upon after 100 years because by that time the potential risks will be reduced by radioactive decay to such an extent that further surveillance should no longer be necessary.

An important feature of the regulations is how wastes are classified. The relative hazard from a radionuclide released into the environment depends on its half-life, physical decay scheme, and its geochemical and biological properties. For example, tritium is the least hazardous of the radionuclides because it emits a very soft beta particle (0.018 Mev), does not concentrate significantly in any parts of the biosphere, and when absorbed into the human body is excreted rapidly (half-life in humans is about 10 days). In contrast, Strontium-90 emits a strong beta particle (more than 2 Mev) and tends to concentrate in the skeleton, from which it is eliminated very slowly with a half-life of about 27 years. The net effect of these variables is on the allowable intake of the various nuclides in drinking water, which are given in the table. It is seen that the allowable concentration for tritium is 3,000 times that allowed for Sr-90.

ANNUAL LIMITS FOR INGESTION OF
CERTAIN RADIONUCLIDES

Annual limit on intake	*(uCi)*
H-3	81,000
C-14	220,000
Sr-90	27
I-131	17
Cs-137	110

Part 61 classifies low level radioactive waste into three classes, A, B, and C, the packaging and disposal requirements for which are progressively more severe. The class A wastes consist generally of the kinds of slightly contaminated trash generated at nuclear reactors and laboratories, and is exempt from most of the stability requirements applicable to other wastes. The class A wastes will have decayed to harmless levels during the 100 period of institutional control. Class B and C wastes must be packaged in containers that will retain their integrity for at least 300 years. There are specified maximum amounts of the more labile nuclides that may be stored for these two classes of wastes.

The hazardous characteristics of both A and B wastes will have diminished sufficiently after the 100 year period of institutional control thereafter to preclude danger to inadvertent intruders. Wastes that will continue to present a danger to intruders after 100 years are called Class C wastes, and must be emplaced at greater depths, or covered by massive concrete barriers to minimize the possibility of inadvertent intrusion. The barriers must retain their integrity for at least 500 years. If the wastes are expected to continue to present a hazard to an intruder after 500 years they are not considered eligible for near surface burial, are called "Greater then Class C wastes," and must be shipped for disposal at a designated government facility. Such wastes are not disposed of in commercial facilities.

THE 1980 LOW LEVEL RADIOACTIVE WASTE POLICY ACT

By 1980 there were only three commercially operated low level radioactive waste repositories, of which only one, at Barnwell, South Carolina, was located in the Eastern part of the country. A crisis was impending because the three state governments were taking actions that would exclude wastes from being imported across their boundaries. Why the states took such drastic actions is not readily apparent, but seems to be related to reluctance to be known as major sites for the disposal of radioactive refuse. Because of the serious implications of the matter, in 1980 the Congress passed the Low Level Radioactive Waste Policy Act, which established as national policy that each state is responsible for providing facilities for the disposal of waste generated by civilian activities within its borders. The Act also suggested that such facilities could be best provided by regional arrangements, or compacts. The three existing repositories, at Barnwell, Beatty, and Hanford, were required to accept wastes from outside their borders until January 1, 1986. Although the states moved rapidly to form and to ratify regional arrangements, it soon became clear that they could not meet the 1986 deadline, and in 1985 the Congress amended the Act to require the three existing sites to remain open for an additional eight years, and other states were required to meet milestones that would result in operation of regional facilities by 1993.

Various regional arrangements have now been largely completed. In the Southeast eight states have formed a compact and have selected North Carolina to be the host state for the 20 year period beginning in 1993. At the end of that time another state will be selected to serve as the host state for the next 20 year period. The various states have opted to comply with the Act in different ways. New York has decided to proceed on its own, without associating with other states.

Some Concluding Thoughts About the Current Situation

The various states and compacts are currently selecting sites for the required facilities, and many of them will soon apply for licenses and begin construction. From the purely technical point of view, the projects should be relatively simple, but their management is complicated greatly by an unusually complex maze of political and legal obstacles. These arise basically from the gap that exists between the actual and perceived risks associated with low level radioactive waste facilities. This troublesome aspect of waste management will be discussed by others in the course of this symposium, but I would like to comment briefly on the impact of the gap in understanding on the management of such waste.

10CFR61 is a thoroughly considered regulation crafted by skilled hands after ample opportunity for comments and suggestions from the public. However, there is a tendency, known as "ratchetting" these days, for local state governments to require features that go beyond the requirements of Part 61. A particularly onerous requirement adopted by many states in response to public pressure is that the facility cannot rely on the integrity of the packages and the characteristics of the soil to retain the wastes, but must provide "engineered barriers" for additional protection. Experience in the field during the past 40 years and thorough study of the problem by the methods of environmental impact analysis have shown that if the site is properly selected there is no need for additional protection. Yet in some states the requirement for engineered barriers has been enacted into law. It would at first seem as though this is a simple enough concession to make if it will eliminate the public concerns. However, geochemists know more about the long-term protective characteristics of clay than civil engineers know about the long-term performance of concrete. Engineered barriers are required by law in one state with which I am familiar, but the law also requires that the site and facility should be able to meet the performance requirements of 10CFR20. It is as though a man doesn't trust his perfectly secure trousers belt and wears suspenders as well! It is my understanding that all of the facilities being built in the eastern United States will be provided with engineered barriers.

To a public health specialist this is a great extravagance. It has been reported that one death from cervical cancer can be prevented by an average expenditure of $25,000, and that deaths from smoke inhalation could be prevented at an average cost of $40,000 by a requirement that all bedrooms be equipped with smoke detectors. (These figures are a bit out of date and the unit costs may now be higher as a result of inflation, but the point I am making will not be affected). Many other examples could be cited to illustrate that premature deaths can be prevented at relatively modest cost.[5,6]

However, in activities associated with modern technology, society is willing to spend far greater amounts of money to avoid premature death. For example, in the control of chemical carcinogens it has been estimated that the unit costs may be as high as hundreds of millions of dollars. Even such costs are dwarfed by the cost-benefit ratios of measures being taken to provide additional protection from the effects of low level radioactive waste facilities. The lowest estimate that has come to my attention of the cost of providing engineered safeguards is about $100 million over the life of the facility. If we take as the objective of the additional safeguards that it will fully eliminate the estimated dose of 0.003 mrem per year to 100 persons who reside near the facility for 50 years and use a risk coefficient of two cases of fatal cancer from a collective dose of 10,000 person-rem, the cost per cancer averted comes to at least tens of *trillions* of dollars. The scientific community should speak out against such nonsense! The main problem seems to be the great gap that exists between the actual risks from low level radioactive waste disposal facilities and the risks as perceived by the public. That important aspect of the matter will be discussed by others at this Symposium.

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